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13. ABSTRACT (Maximum 200 words) The overall objective is to demonstrate both the technical and economic feasibility of using a fluidized bed system, initially developed for heat treatment, quenching, and aging of premium aluminum sand castings, to separate castings from sand molds, to de-core internal passageways in the castings, to reclaim the sand for re-use, and to use the binder resins from the molds and waste sand from mold building as a partial source of energy supply for the operation. This system will replace the mechanical shaker tables and hot air convective ovens currently used to remove sand and de-core premium aluminum castings from resin-bonded sand molds.			
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Phase I Final Report

Contract Number
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MDA04-111 Innovative Manufacturing Process Improvement

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Overall Phase I Project Objectives

The overall objective is to demonstrate both the technical and economic feasibility of using a fluidized bed system, initially developed for heat treatment, quenching, and aging of premium aluminum sand castings, to separate castings from sand molds, to de-core internal passageways in the castings, to reclaim the sand for re-use, and to use the binder resins from the molds and waste sand from mold building as a partial source of energy supply for the operation. This system will replace the mechanical shaker tables and hot air convective ovens currently used to remove sand and de-core premium aluminum castings from resin-bonded sand molds.

A small fluidized bed unit was rented from Keppel Seghers Inc. for the required experimentation. This fluidized bed has a small 2'x2'x5' working zone and was designed to strip paint and other organics from metal parts. A photo of this rental unit is shown below.



Specific Phase I Project Objectives

The project objectives were as follows:

1. **Objective 1:** Verify if the use of a precision fluidized bed can reduce the overall time required to de-core complex structural castings by at least 75%. The current process requires 24 – 72 hours; the target is 3 – 5 hours but 6 – 18 hours would be considered successful results
 - a. **Experiment 1 Results:** Multiple 1ft³ blocks of cured core sand were processed through the fluidized bed to determine the rate of binder breakdown by monitoring the temperature of the block in multiple locations (ref figure 1). These blocks constantly experienced complete binder breakdown in less than 2 hours (ref figures 2 and 3).

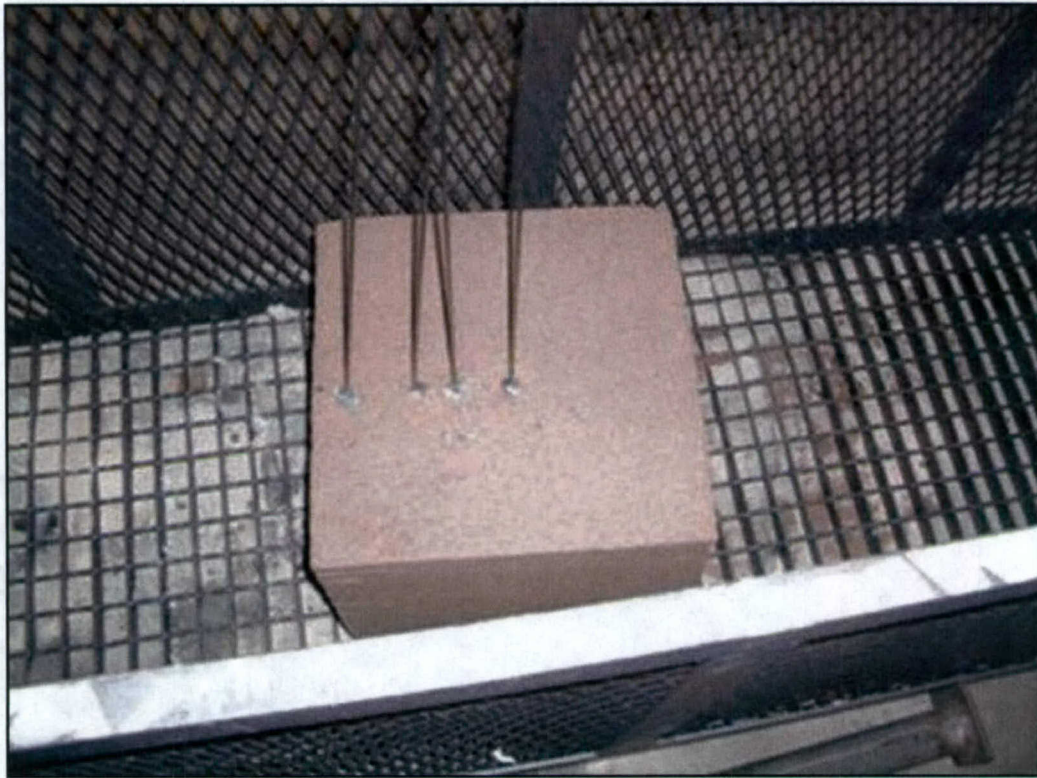


Figure 1

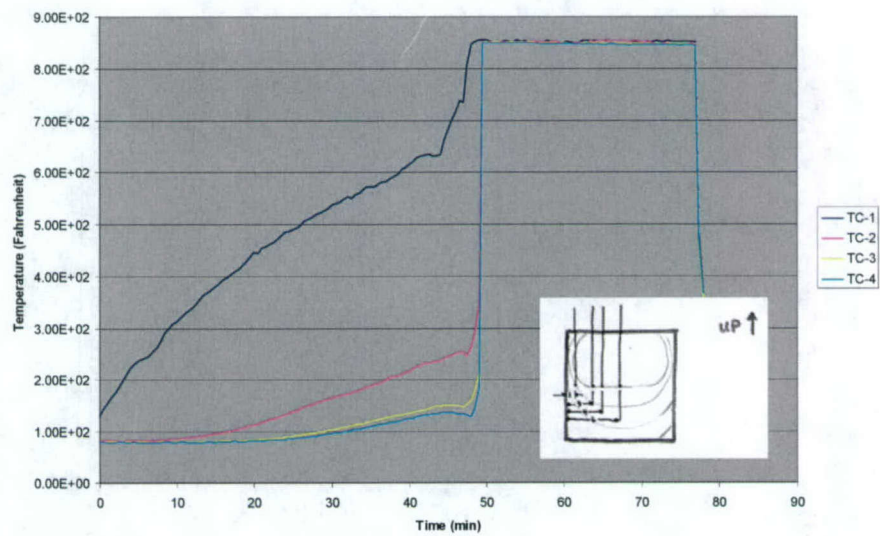
Temperature vs. Time for 1ft Sand Cube Bakeout

Figure 2

Temperature vs. Time for Fluidized Bed Bakeout of 1ft Cube (dimensions are from bottom of cube in inches)

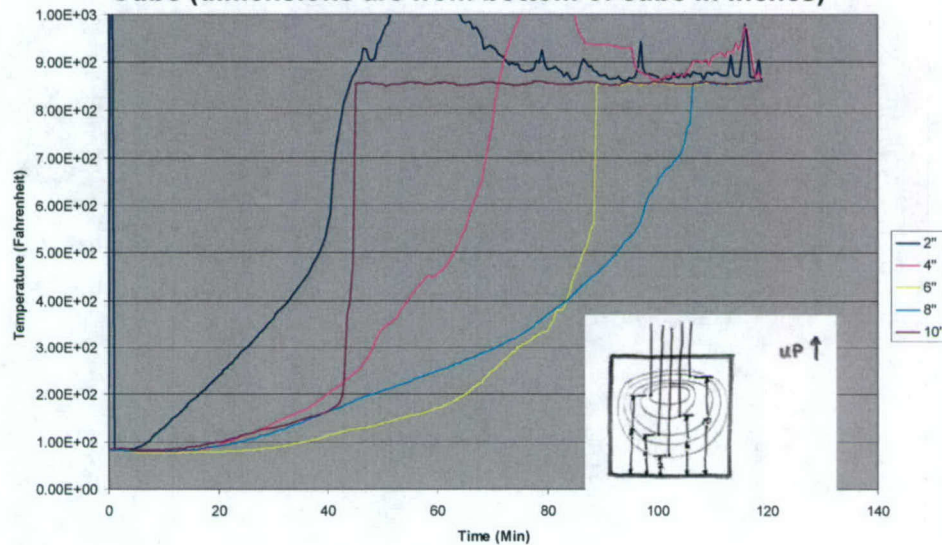


Figure 3

In both Figures 2 and 3 the time for complete binder breakdown is determined by the time for each thermocouple location to reach the fluidized bed temperature.

- b. Experiment 2 Results:** Experiment 2 consisted of processing an actual production part through the fluidized bed (ref figure 4 showing after gate removal and with the gating attached as processed through the mold removal process).



Figure 4

The normal process for the part chosen is a 3 step process.

- i. A manual removal of the external mold using a vibratory table.
- ii. 2 - 10 hour bakeout cycles in a standard oven for a total oven time of 20 hours.
- iii. A manual stationary "rap" process to remove the internal coring using a high impact vibratory clamping machine.

The process utilized for this task was to determine if the complete 3-step process could be reduced to a single-step process and determine the time required for complete mold removal. The mold was loaded into the fluidized bed, as shown in figure 5, with no pre-processing.



Figure 5

The mold was then removed in 1-hour increments and visually inspected for complete mold removal. These inspections are shown in figures 6 through 8.



Figure 6 - 1 Hour Process Time @ 850°F



Figure 7 - 2 Hour Process Time @ 850°F



Figure 8 - 3 Hour Process Time @ 850°F

The casting was then processed through the manual stationary "rap" process and was found to have had 100% of the internal coring removed in the fluidized bed there by eliminating the need for the "rap" operation.

c. Objective 1 Conclusion: Objective 1 is considered to be a complete success. The thermal process time was reduced from the current 20-hour process to the fluidized bed 3-hour process. This represents an 85% reduction in cycle time and also had the added benefit of eliminating 2 manual operations. The overall cycle time to process the part through the complete core removal processes is thereby reduced from 3 days to 4 hours when including queue time at each process step.

2. Objective 2: Determine if the use of the fluidized bed will enable sufficient reclamation and reuse of waste mold sand from both post-casting and pre-casting processes. The goal is to eliminate the disposal costs of approximately \$80 per ton - \$8000/week at Hitchcock. Reclamation and re-use of at least 75% of sand is the project's minimum target.

a. Experiment 3 Results: The fluidized bed was filled with mechanically reclaimed sand that was analyzed for grain size and distribution, percent of volatile organics, i.e. LOI or Loss On Ignition, and moisture percentage. After all experimentation was completed, the sand in the fluidized bed was re-analyzed and compared to the mechanically reclaimed results and that of new sand.

i. Grain size and distribution: The sand grain size and distribution of the fluidized bed sand compared to the mechanically reclaimed origin and new sand is shown in figure 9. The fluidized bed sand shows a much tighter distribution around the mean target screen mesh with lower amounts present in the coarse screens, 20 to 40 mesh and in the fine screens, 200 to pan, with the greatest impact of the two being the reduction in fine grains. This is more clearly represented in figure 10 when the 200, 270 and Pan are combined. These three screens consist of what is commonly referred to as dust. While the percentages are not large, this dust can have a significant impact on foundry issues and the fluidized bed sand has 46% less dust than the mechanically reclaimed sand and even has a 30% reduction compared to new sand. This reduction in dust will benefit the foundry in several areas as follows:

1. Lower levels of airborne "free silica" that is been proven to be a carcinogen.
2. Improved core permeability and resultant reduction in gas related casting defects.
3. Reduced binder levels required for the desired core strength.

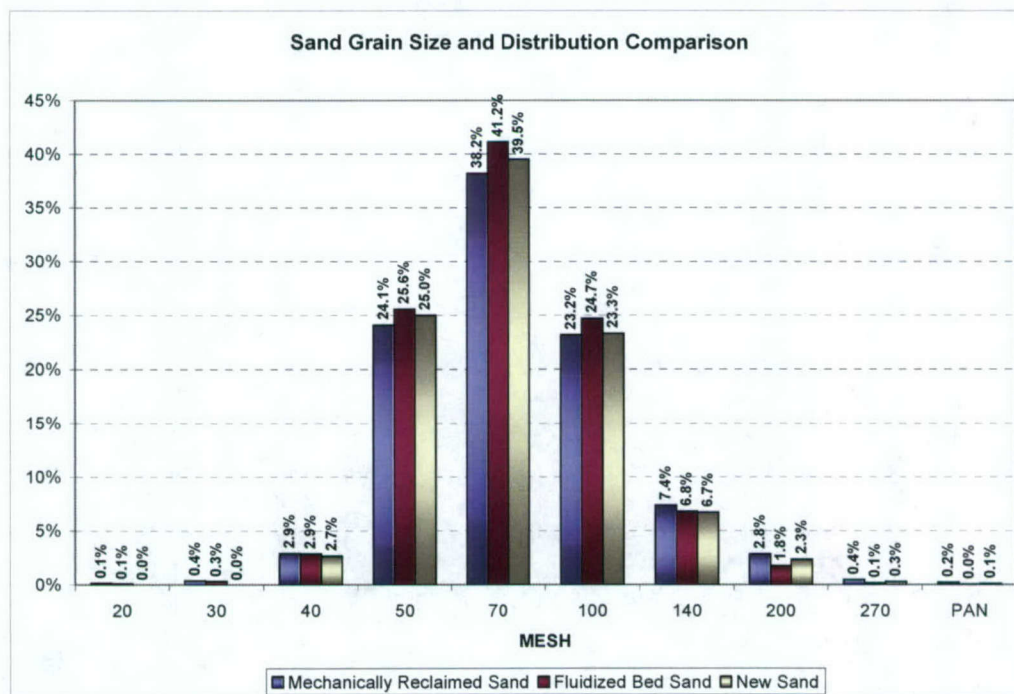


Figure 9

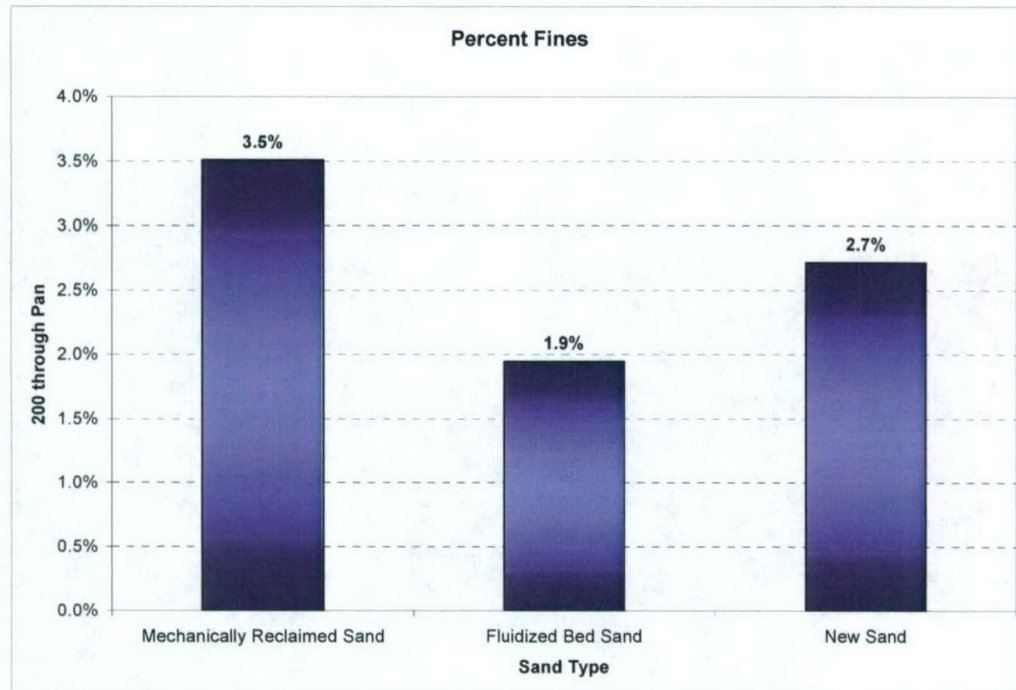


Figure 10

- ii. **Volatile Organics:** Volatile organics is another key measurement to determine the quality of foundry sand. This is measured in terms of LOI or Loss On Ignition and is the measurement of the percentage of the core that burns off during the casting process. As the LOI increases, more gasses are produced by the core and thereby increase the probability of gas related defects in the casting. As shown in figure 11, there is a significant reduction in LOI, 95% reduction, by treating the mechanically reclaimed sand in the fluidized bed and even shows a 33% reduction compared to new sand.

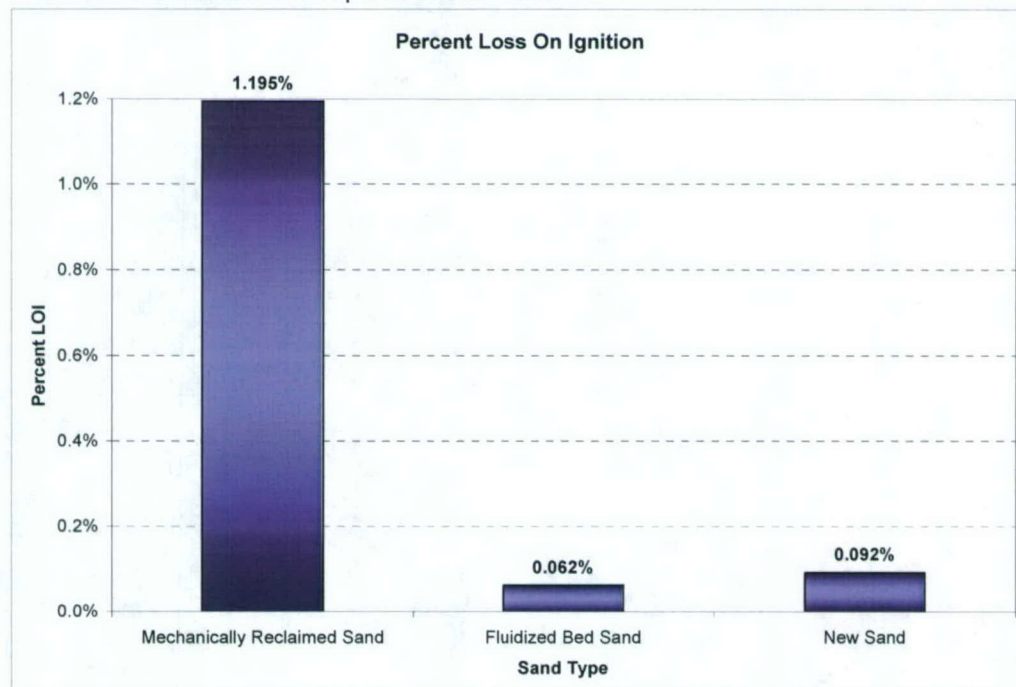
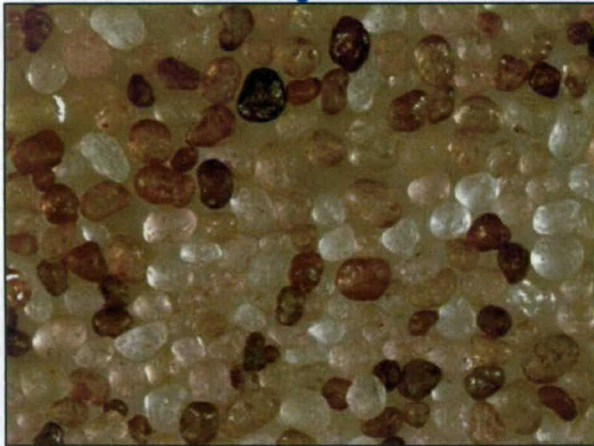


Figure 11

Further microscopic analysis of the sand grain morphology supports the above data for the cleanliness of the fluidized bed sand. The results in figures 12 through 14 confirm the significant improvement from the fluidized bed processing of the mechanically reclaimed sand.

20X Magnification

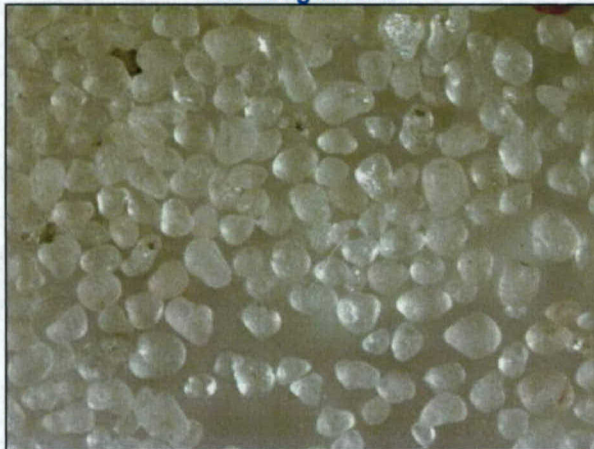


50X Magnification



Figure 12 – Mechanically Reclaimed Sand Morphology

20X Magnification



50X Magnification

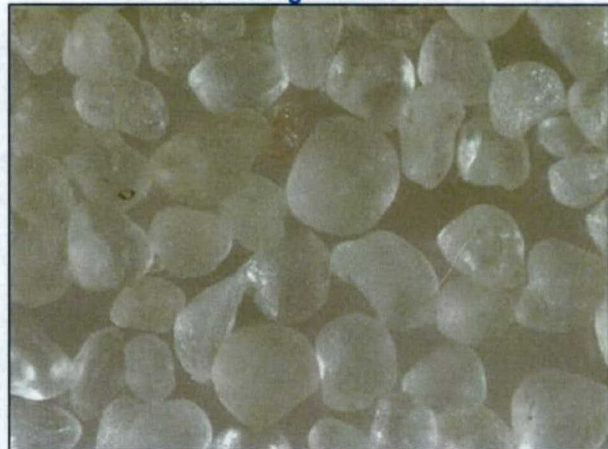
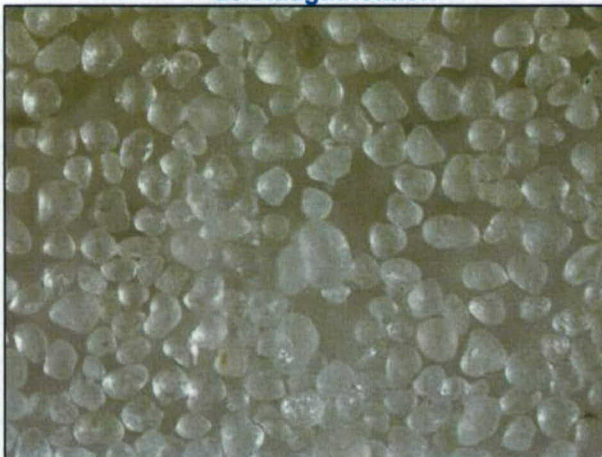


Figure 13 – Fluidized Bed Processed Sand Morphology

20X Magnification



50X Magnification

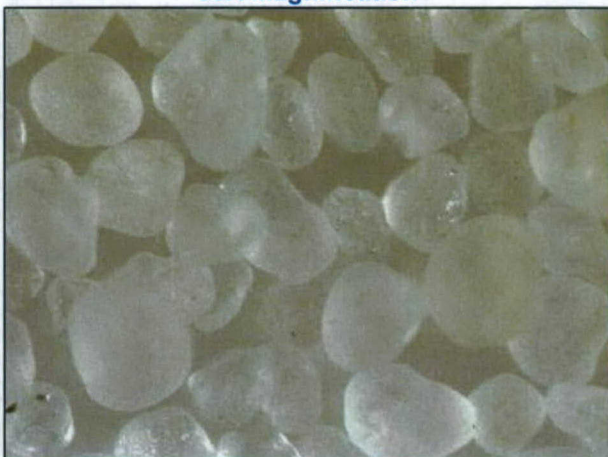


Figure 14 – New Sand Morphology

- iii. **Moisture:** The presence of moisture in the sand can have a significant impact on core strength due to its negative impact on the core binders with regard to core strength. The

fluidized sand shows a 62% reduction in moisture compared to the mechanically reclaimed sand and a 29% reduction compared to new sand as shown in figure 15.

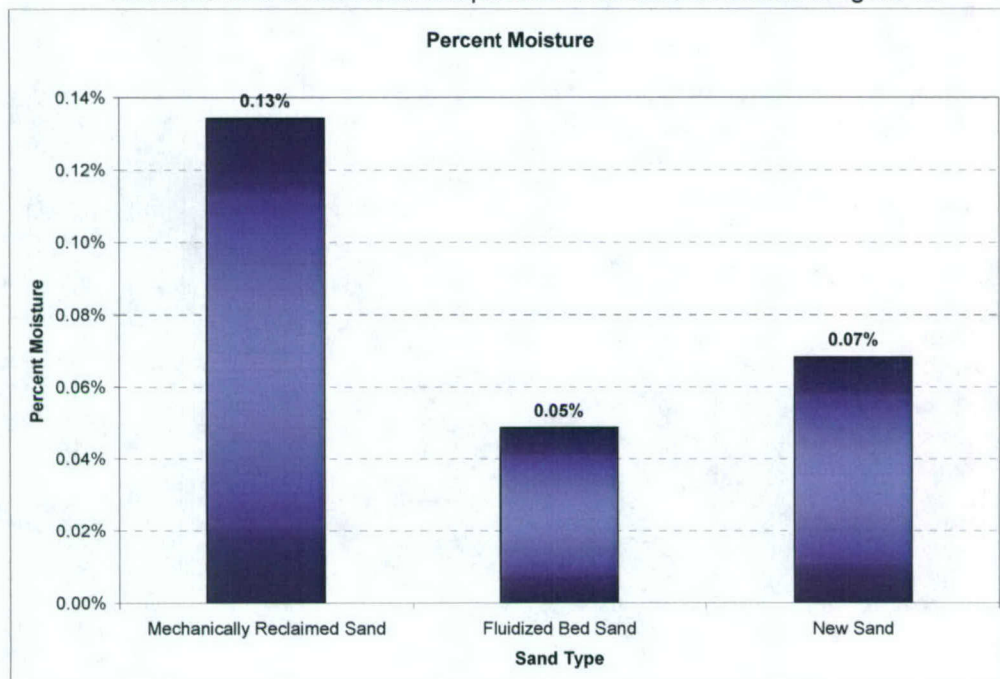


Figure 15

- b. **Experiment 4 Results:** Cores were manufactured using the mechanically reclaimed sand and the fluidized bed sand and tested for ultimate strength. Based upon the results in Experiment 3, the fluidized bed sand cores were manufactured with 21% less binder than the mechanically reclaimed sand cores. The results in figure 16 show that even with the lower binder levels, the fluidized bed sand cores tested significantly higher for strength with ultimate strength being 170% greater.

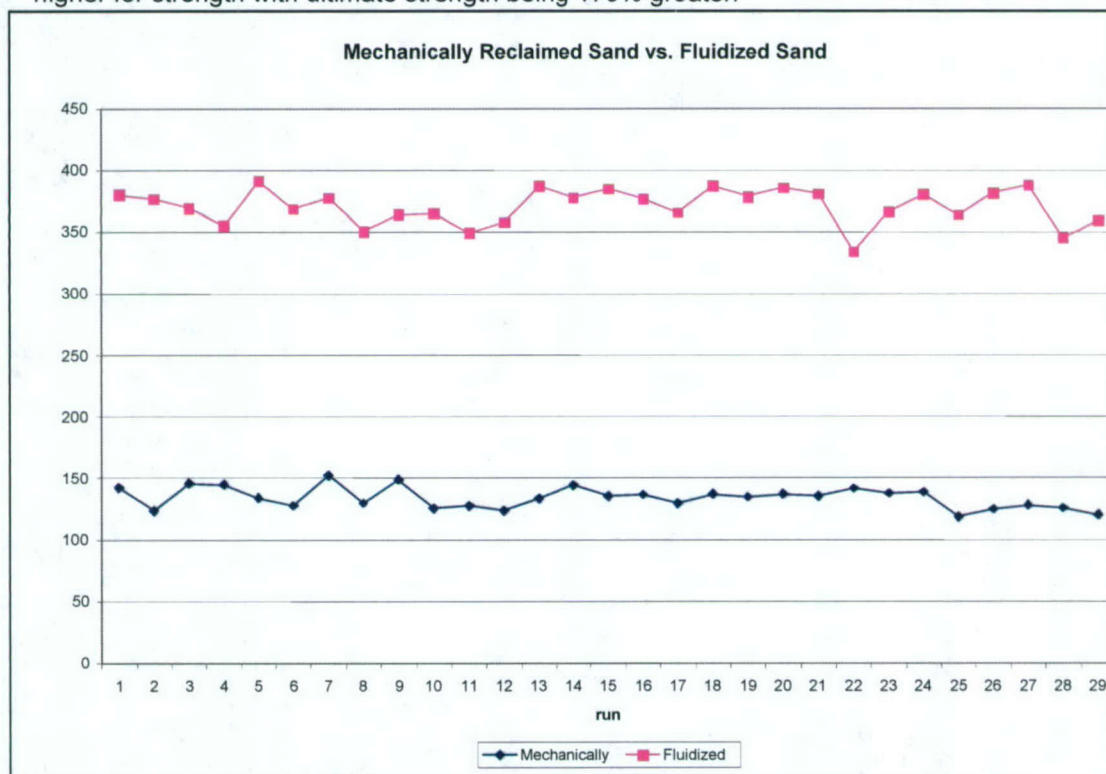


Figure 16

c. **Objective 2 Conclusion:** In all tests performed the fluidized bed sand tested significantly better than the mechanically reclaimed sand and to a lesser degree better than new sand. While full evaluation for comparison on a production setting was not possible due to the small amount of product that could be processed through the fluidized bed due to size restrictions, the data shows that the process would exceed the expected sand savings of 75% and could approach 95% savings in sand cost and also yield a 20% binder savings.

3. **Objective 3:** Measure the extent to which the fluidized bed will incinerate the resin coated sand mold materials, and what caloric value the resin has in being used as a fuel. The goal is to obtain at least 15% of the system's heating energy from incineration of the resins.

a. **Experiment 5 Results:** The presence of caloric value in the resin, of binder, was tested by introducing 2 1ft³ blocks of sand into the fluidized bed and monitoring the overall temperature of the bed. Figure 17 shows that after an initial 3°F cooling of the bed when the blocks were introduced, approximately 2000 seconds after the temperature monitoring was initiated, that the bed temperature rose by 7°F once the resin started to ignite. This caloric value of the resin was also observed in Experiment 1, figure 3, that shows individual thermocouples exceeding the bed temperature at different time intervals based on the location of the thermocouples.

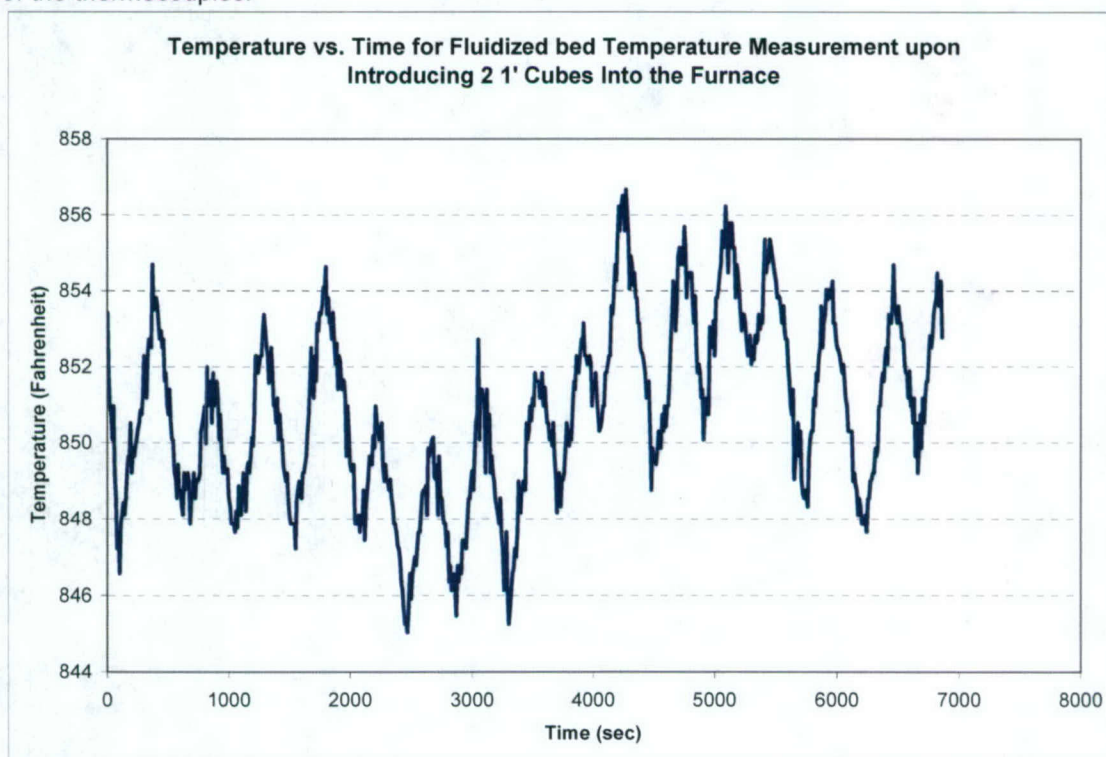


Figure 17

b. **Objective 3 Conclusion:** The existence of caloric value from the resin does exist. The amount of energy that can be realized could not be calculated and will be dependant on determining, in a production setting, the optimum size of the load compared to the fluidized bed volume and the time from pour to mold stripping in the fluidized bed to also utilize the caloric value saved by processing the mold while the casting inside is still hot from the pouring process. This residual heat value is not an option in the current 3-step process since the casting material has a very low strength at high temperatures and would not survive the violent action of the vibratory table mold stripping method.

4. **Objective 4:** Analyze the effects of using the fluidized bed as the separating and de-coring process on the dimensional consistency of complex thin-walled structural aluminum castings. In the current process all thin-walled castings will suffer some distortion and require straightening. The current process is to pour walls thicker than the optimum for the end use. The project goal is to achieve at least 50% improvement in dimensional accuracy and consistency by using the fluidized bed.

a. **Experiment 6 Results:** No results were available due to the size restrictions of the rental fluidized bed. The time to build a bed of sufficient size would have exceeded the time allotment of this Phase I activity.

- b. Objective 4 Conclusion:** While no results were available, the non-violent action of the fluidized bed and lack of damage caused to the small castings processed does indicate that dimensional improvement has a high probability.
- 5. Objective 5:** Determine the potential for reducing the amount of aluminum required to produce an eventual net weight component by reducing the need for external gating currently required to protect the casting during shake-out. In the present process, 80 – 85% of the aluminum poured is removed to achieve the final part. A twelve-pound component, for example, requires 150 pounds of aluminum. The goal is to reduce cast weight by at least 30%, enabling foundries to buy, melt, and remove less aluminum for final net weight.
- a. Experiment 7 Results:** Four small castings were tested and resulted in a 40%, 30%, 25% and 17% reduction in pour weight. These castings show no signs of damage from the fluidized bed mold stripping process.
- b. Experiment 7 Conclusion:** While these castings did not all experience the goal of 30% reduction in the pour weight, they are small castings due to the fluidized bed size, the potential for greater savings are evident in the larger product due to the amount of gating required to support the large casting during the traditional mold stripping process.

Technical Feasibility

In all experiments the results exceeded the expectations. Additional production parts were also processed through the fluidized bed during second shift operations and virtually eliminated production rework on those parts due to entrapped sand in the casting which can be detected by radiographic inspection of the parts. The feasibility of building a larger scale production unit is also extremely high in that these units have already been built for other applications.

Phase II Transition Plan

Many technologies show promise in scale-model and demonstration tests yet do not yield anticipated benefits in actual production use. Other new technologies reveal unanticipated drawbacks or even hazards once commercially deployed that were not evident in trials.

Thus, Phase II will involve:

- Installation of a full-scale fluidized bed system to de-core castings and reclaim the sand with a cooling station and automated transfer of sand. The system will be installed adjacent to the casting area in order to test and validate the reliability and repeatability of these Phase I results in a standard production environment. Standard aluminum alloy components will be processed at production rates and analyzed for final properties achieved. Actual energy use, as well as solid waste and air emissions, will be compared with rates for conventional de-coring and sand reclamation;
- Results in the production environment will be analyzed to determine optimum settings for the system's complex variables, such as load percentage and media fluidization rates, vis-à-vis the characteristics and design of various components being processed;
- Redesign of actual components for reduced gating and thinner walls, testing of the redesigned components in the system, and analysis of the consistency and quality of the redesigned components once processed in the system;
- Determine energy savings achieved by use of binders in used sand as a fuel for heating the system.